9.

9. EVALUATION OF ALTERNATIVES

The remediation alternatives described in the previous chapter are evaluated in this chapter. The evaluation concludes with a discussion of the overall evaluation and scoring, and identification of the preferred alternative.

9.1 Threshold Evaluation

Under MTCA, remediation alternatives must meet the following threshold requirements (WAC 173-340-360(2)):

- Protection of human health and the environment
- Compliance with cleanup standards
- Compliance with ARARs
- Provision for compliance monitoring

Each alternative is evaluated individually against the threshold criteria in the following sections.

9.1.1 Protection of Human Health and the Environment

As a threshold criterion, protection of human health and the environment addresses whether a remediation alternative would result in sufficiently low residual risk to human and ecological receptors after completion of the alternative, resulting in a minimum acceptable level of protection. The relative degree of protection provided by the alternatives is considered in the comparative evaluation. One measure of sufficient protectiveness is the second threshold criteria, compliance with cleanup standards (see Section 9.1.2). Evaluation of protection of human health and the environment also considers short-term risks posed by remedial action (i.e., if remedial action could result in as much harm as benefit).

The fact that no current groundwater risk was found, even with an open trench that collects stormwater and promotes its infiltration to groundwater, indicates the low risk posed by this site. However, Alternative 1 does not mitigate potential exposure pathways (i.e., potential constituent migration in groundwater, surface water, and airborne dust). Alternative 9 (Excavation and Disposal) is only protective if it can be implemented reliably, which is questionable. In addition, the short-term risks posed by excavation in Alternative 9 offset much of the potential benefit of waste removal from the site.

All of the other alternatives prevent direct exposure to any waste and affected soil in the trench or site groundwater in the event it were to become affected by waste constituents from the site. The cap alternatives (4 through 7) also prevent off-site migration in surface water or airborne dust, and decrease the quantity of infiltration through the trench disposal area, as expected for containment actions per WAC 173-340-360(8)(f). Alternative 2 (Institutional Controls and Monitoring) does not meet this regulatory expectation.

9.1.2 Compliance with Cleanup Standards

Compliance with cleanup standards is defined by meeting the requirements of WAC 173-340-700 through -760. Compliance with cleanup standards does not require removal of all waste or affected soil from a site; these regulations include provisions for meeting cleanup standards through containment (e.g., WAC 173-340-700(2)(b) and (c)).

All of the alternatives except Alternative 1 (No Action) would comply with MTCA cleanup standards. Alternative 2 (Institutional Controls) would rely on institutional controls. Alternative 9 (Excavation and Disposal) is the only alternative that would meet cleanup standards by removal of waste and affected soil from the site. The remaining alternatives would rely on containment (natural and engineered).

9.1.3 Compliance with ARARs

Compliance with ARARs addresses whether an alternative complies with all applicable or relevant and appropriate requirements (ARARs), as defined in Chapter 4.

Alternative 1 (No Action) does not comply with ARARs because it does not comply with cleanup standards in accordance with WAC 173-340-700. Alternatives 2 (Institutional Controls and Monitoring) and 4 (Soil Cap) do not comply with all ARARs because they do not meet the minimum functional standards (MFS) for a landfill cap under WAC 173-304. In addition, Alternative 2 does not meet the regulatory expectation of preventing stormwater run-off from contacting waste materials under WAC 173-340-360(8)(f).

All of the other alternatives comply with all ARARs, including the applicable or relevant and appropriate sections of WAC 173-303 and 173-304.

9.1.4 Provision for Compliance Monitoring

Compliance monitoring requirements are defined at WAC 173-340-410. Compliance monitoring includes: 1) "protection monitoring" to confirm that human health and the environment are adequately protected during implementation of an alternative; 2) "performance monitoring" to confirm that cleanup standards or other performance standards (e.g., cap permeability) have been attained; and 3) "confirmational monitoring" to monitor the long-term effectiveness of the remedy after completion of the alternative.

Alternative 1 (No Action) does not provide compliance monitoring, and therefore does not meet this requirement. Alternative 9 (Excavation and Disposal) would include protection and performance monitoring during remedial action, but would not require long-term monitoring (if successful) because all waste and affected soil would be removed from the site, and therefore meets this requirement. All of the remaining alternatives meet this requirement by providing appropriate protection, performance, and confirmational monitoring.

9.1.5 Summary of Threshold Evaluation

Based on the preceding evaluations, the following alternatives do not meet one or more of the MTCA threshold criteria for selection as the preferred alternative:

Alternative 1 (No Action)
Alternative 2 (Institutional Controls and Monitoring)
Alternative 4 (Soil Cap).

The remaining alternatives meet the minimum requirements of the MTCA threshold criteria.

9.2 Use of Permanent Solutions

WAC 173-340-360(3) specifies that the remediation alternatives must use permanent solutions to the maximum extent practicable. WAC 173-340-360(5) specifies that "Ecology recognizes that permanent solutions [defined at WAC 173-340-360(5)(b)] may not be practicable for all sites. A determination that a cleanup action satisfies the requirement to use permanent solutions to the maximum extent practicable is based on consideration of a number of factors." The specified factors, or criteria, are:

- Overall protectiveness
- Long-term effectiveness and reliability
- Short-term effectiveness
- Reduction in toxicity, mobility, and volume
- Implementability
- Cost
- Community acceptance

These criteria and the basis for evaluating the alternatives against them are defined and discussed below. These definitions are consistent with MTCA regulations, but have been refined to minimize the overlap of considerations in the criteria. This allows decision makers to consider each criterion independently and minimizes double-counting of criteria. In addition, use of independent criteria allows better comparisons between the criteria; i.e., determining the value of each criterion in terms of the other criteria. Well-defined criteria minimize misunderstandings between the concerned parties and facilitate effective communication during selection of a preferred alternative.

9.2.1 Overall Protectiveness

Overall protectiveness addresses the degree to which each alternative attains cleanup standards and is protective of human health and the environment, considering both long-term and short-term risks. This criterion is derived from the evaluation of the other criteria. It is not an independent criterion, but more a summary of the overall evaluation. Therefore, the overall comparative evaluation (net benefit) of the other non-cost criteria is taken as the overall protectiveness of the alternative. In addition, overall protectiveness is evaluated as a threshold criterion in Section 9.1.1.

9.2.2 Long-Term Effectiveness and Reliability

This criterion addresses risks remaining at the site after the remediation alternative has been implemented, and the reliability of the alternative at reducing risks over an extended period of time. Risks during the implementation period are addressed under short-term effectiveness. Evaluation of long-term effectiveness involves estimation of the residual risk associated with each alternative in comparison to baseline risk, and can be measured by the degree to which remedial action objectives are met (Section 7.1). Reliability involves estimating the longevity of the remedy, (e.g., the lifespan of institutional controls or containment) and the chances of remedy failure.

This criterion is evaluated using the following two sub-criteria:

1. Long-term effectiveness

- The alternatives are qualitatively compared for reducing the magnitude of residual risk, including meeting RAOs. The long-term effectiveness criterion addresses both residual human health and ecological risk. However, for this site there is no need to evaluate alternatives for these risks separately. Each alternative provides long-term effectiveness by eliminating or controlling pathways of exposure for human health risks in the same manner as ecological risks. Therefore, there would be no difference in the comparative analysis between alternatives if these risks were evaluated separately.

- Relative reduction in infiltration after remediation was taken as an objective measure of long-term effectiveness or risk reduction.

2. Reliability

- Reliability addresses "the degree of certainty that the alternative will be successful" as specified in WAC 173-340-360(5)(d)(ii).

- Alternatives are qualitatively evaluated for their reliability in achieving the anticipated degree of effectiveness (i.e., immediately after completion of remedial action).

- Alternatives are qualitatively evaluated for the estimated longevity of the remedy *at its expected degree of effectiveness*. An alternative that scores less than another for effectiveness can score higher for reliability if it is expected to maintain its effectiveness longer or more reliably.

- Reliability includes qualitative evaluation of the amount of long-term maintenance and monitoring required. The greater the requirement for maintenance and monitoring, the lower the reliability.

The overall score for this criterion is obtained by giving equal weight to the two sub-criteria.

9.2.3 Short-Term Effectiveness

This criterion addresses short-term effects on human health and the environment while the alternative is being implemented. The evaluation includes consideration of the following factors:

- Risk to site workers
- Risk to the community
- Risk to the environment (short-term ecological risk)
- Time needed to complete remedial action.

Short-term effectiveness was primarily scored based on evaluation of the degree of risk to site workers. The primary risk to site workers would be due to construction accidents. In addition, for cap alternatives, the relative complexity of the caps is a measure of the relative man-hours required, and therefore the relative worker risk.

Because remedial action would include controls as necessary to ensure that the remedy does not create an unacceptable risk to the community, risk to the community is not as significant in distinguishing between alternatives as worker risk. However, Alternative 9 (Excavation and Disposal) would create the potential for human exposure to off-site release of excavated waste during remedial action, and this risk is considered in the evaluation. The considerations for ecological risk are very similar to those for community risk, in that Alternative 9 would create potential for ecological exposure to release of excavated waste during remedial action. The other alternatives do not involve these risks.

Time to complete remedial action includes preparation of MTCA planning documents, remedial design, Ecology and public review, and implementation time. Time estimates are from completion of the final CAP.

9.2.4 Reduction of Toxicity, Mobility, and Volume

This criterion addresses the degree to which a remediation alternative reduces the inherent toxicity, ability of contaminants to migrate in the environment, or the quantity of contaminated material. This criterion is also used to expresses the preference hierarchy for cleanup technologies under 173-340-360(4), and the use of recycling or treatment under WAC 173-340-360(5). Effectiveness and reliability of the treatment, which are addressed under long-term effectiveness and permanence, are not addressed under this criterion.

9.2.5 Implementability

This criterion addresses the degree of difficulty in implementing each alternative. Implementability issues are important because they address the potential for delays, cost overruns, and failure. Known implementation difficulties with quantifiable cost impacts are included in the cost estimates. The implementability criterion focuses on less quantifiable known and potential difficulties. Implementability is evaluated considering the following:

- **Technical Feasibility.** Technical feasibility addresses the potential for problems during implementation of the alternative and related uncertainties. The evaluation includes the likelihood of delays due to technical problems and the ease of modifying the alternative, if required.

- **Availability of Services and Materials.** The availability of experienced contractors and personnel, equipment, and materials needed to implement the alternative. Availability of disposal capacity is also included in the evaluation.

- **Administrative Feasibility.** The degree of difficulty anticipated due to regulatory constraints and the degree of coordination required between various agencies.

- **Scheduling.** The time required until remedial action would be complete, and any difficulties associated with scheduling.

- **Complexity and Size.** The more complex or larger a remedial action, the more difficult it is to construct or implement. In addition, the more items there are that can go wrong, the greater the chance of failure that could affect remedy effectiveness.

- **Other Considerations.** Monitoring requirements, access for construction and operation and maintenance, integration with existing operations and current or potential remedial action, and other factors were considered in accordance with WAC 173-340-360(5)(d)(v).

9.2.6 Cost

This criterion is used to consider the costs of performing each alternative, including capital, operation and maintenance, and monitoring costs. Alternative costs are compared on a net present value basis. Known implementation difficulties with quantifiable cost impacts are included in the cost estimates.

9.2.7 Community Acceptance

After the FS is finalized, an alternative is selected as the proposed remedial action. The proposed remedial action is described along with the basis for its selection in the draft Cleanup Action Plan (CAP). Determination of community concerns is based on public comments on the draft CAP. Therefore, community acceptance is not included in the FS comparative evaluation. Instead, Ecology evaluates community acceptance after the FS is completed. The proposed remedial action may be modified to address community concerns based on public comments on the draft CAP.

9.3 Comparative Evaluation Methodology

Selection of a remediation alternative is based on comparative evaluation of the alternatives (that satisfy the threshold criteria) using 5 permanence criteria: 1) long-term effectiveness and reliability, 2) short-term effectiveness, 3) reduction in toxicity, mobility, and volume, 4) implementability, and 5) cost. Overall protectiveness and community concerns are not included in the comparative evaluation for reasons discussed in Section 9.2. The following methodology was used for the comparative evaluation:

1. Each alternative is scored relative to the other alternatives for the 4 non-cost permanence criteria. Because of the nature of the criteria and the uncertainties in the evaluation, the scores for these 4 criteria are expressions of relative qualitative or semi-quantitative professional judgments. A scale of 0 (worst) to 10 (best) is used. Qualitative scoring for the criteria is appropriate and is typically conducted when the information to provide meaningful and defensible quantitative scoring is not available. Estimated infiltration rates were used to provide a quantitative basis for scoring the long-term effectiveness of cap alternatives.

2. The relative values of the non-cost criteria are determined. The relative criteria values are expressions of what a scoring unit of one criterion is worth compared to a scoring unit of another criterion. In other words, relative criteria values express how much a decreased value (lower score) of one criterion is acceptable to obtain an improvement (higher score) for another criterion. The relative criteria values are dependent on the scoring scales; a change in the basis of the scoring (i.e., scoring scale) requires changing the relative values assigned to the criteria to express the same value system. The assigned relative values are converted to criteria weightings, i.e., percentage of the overall score.

3. The scores for the 4 non-cost criteria are combined using the criteria weightings to give overall alternative scores. These scores express the net benefit of the alternatives.

4. A comparison of the cost and benefit of the alternatives is made. The alternative with the best benefit and cost:benefit ratio is the preferred alternative.

5. Sensitivity analyses are provided to show how remedy selection is affected by potential variations in scoring or relative criteria values.

As the expression of a value system, relative criteria values are inherently subjective. For this FS, criteria values were assigned relative to the criterion of long-term effectiveness and permanence. For example, assigning a relative value of 0.5 to a short-term effectiveness means that this criterion is taken to be half as important as long-term effectiveness. In terms of trade-offs between criteria, increasing the short-term effectiveness score of an alternative by 2 (for a given scale used to score short-term effectiveness) would be equivalent to increasing the long-term effectiveness and reliability score by 1 (for a given scale used to score long-term effectiveness and reliability); either change would result in the same change to the overall score.

The best professional judgment of the FS authors was used to set the relative criteria values for this FS. Given the criteria definitions and basis for scoring used in this FS, the following criteria values were assumed relative to the criterion of long-term effectiveness and reliability:

Criterion	Relative Value
Long-term effectiveness and reliability	1
Short-term effectiveness	0.4
Reduction in toxicity, mobility, and volume	0.1
Implementability	0.4

It is important to note that the relative value assumed for reduction in toxicity, mobility, and volume is based on the definition of this criterion in Section 9.2.4. Reduction in toxicity, mobility, and volume is generally considered important because it is associated with improved long-term effectiveness and reliability. However, the comparative evaluation used herein assumes independent criteria. Therefore, the reduction criterion has been defined as expressing the cleanup technology hierarchy under WAC 173-340-360(4) and the preference for permanent solutions under WAC 173-340-360(5)(a), *apart from the resultant improvements to long-term effectiveness and reliability*. The improvements to long-term effectiveness and reliability resulting from treatment or other reduction in toxicity, mobility, and volume are accounted for under the criterion of long-term effectiveness and reliability. This approach avoids double-counting benefits.

9.4 Evaluation of Remediation Alternatives for Permanence

This section provides a comparative evaluation of the alternatives using 5 of the 7 permanence criteria (see Sections 9.2 and 9.3). For completeness and perspective, all of the retained alternatives are included in the evaluation, even if they do not meet the threshold criteria (evaluated in Section 9.1). The basis for the scoring is provided below. The evaluation and scoring of the alternatives is summarized in Table 9-2.

9.4.1 Long-Term Effectiveness and Reliability

Restricted access to the trench, where any waste is located, already limits direct exposure to constituents of concern. The relatively greatest potential for migration of and exposure to site constituents is via groundwater. The fact that groundwater meets remediation goals (cleanup levels), even with an open trench that collects stormwater and promotes its infiltration to groundwater, indicates the lack of current risk posed by this site. Evaluation of this criterion was therefore based on the ability of the alternatives to reduce potential future risks.

9.4.1.1 Effectiveness

Alternative 1 (No Action) does not decrease site risks, and is therefore given an effectiveness score of 0. Alternative 2 (Institutional Controls) provides some decrease in site risk, but much less than capping or excavation and off-site disposal. Alternative 2 is therefore given an effectiveness score of 1. Alternative 9 (Excavation and Disposal) is given a score of 10 on the assumption that all waste could be removed.

The infiltration as a percentage of no-action infiltration is used as the basis for the effectiveness scores of the cap alternatives. The relative performance of the various cap designs was estimated using the Hydrologic Evaluation of Landfill Performance (HELP) Model, Version 3.01 (EPA 1994), and site-specific monthly temperature and precipitation data. The results are summarized in Table 9-1; HELP input and output data are presented in Appendix G. For comparison purposes, the total inflow to the trench under current conditions was also estimated. This inflow is the sum of the runoff from the surrounding area (see Figure 8-2) and the precipitation falling directly into the trench. Runoff from outside the trench was estimated using the HELP model and is roughly equal to the estimated current infiltration due to precipitation falling directly in the trench. Thus, regrading and ditches alone would significantly reduce infiltration through trench waste and affected soil. The estimated net reduction in infiltration by the various caps (Table 9-1) include the benefits of stormwater controls.

The effectiveness scores for the cap alternatives are the estimated percent reduction in infiltration divided by 10 (to match the 0 to 10 scale), less 0.5 score units to reflect that on-site containment is somewhat less effective than destruction or off-site containment in a lined landfill. On this basis, the cap alternatives scores are:

Alternative	Score
Alternative 4: Soil Cap	5.7
Alternative 5: Low-Permeability Soil Cap	8.3
Alternative 6: FML Cap	9.0
Alternative 7: FML/GCL Composite Cap	9.5

9.4.1.2 Reliability

The sub-criterion of reliability is scored based on professional judgment and experience in the ability of the remedies to achieve and maintain their estimated effectiveness. As the base case, Alternative 1 (No Action) is given the score of 0. Under MTCA, the reliability of institutional controls is considered low in comparison to engineered containment or removal; Alternative 2 is therefore given a score of 1.

As discussed in Section 8.2.6, it is highly questionable that excavation, if implementable, could be certain of removing all waste from the trench. In addition, there is a significant risk of spreading contamination around the site and a high likelihood of impacts to groundwater. Alternative 9 is therefore has poor reliability. It is given a score of 4, which is higher than Alternatives 1 and 2, but lower than the cap alternatives.

Alternatives 4 (Soil Cap) and 5 (Low-Permeability Soil Cap) are both very reliable because of their longevity, thickness, ease of maintenance and repair, and simplicity. Unlike synthetic liners, soil layers do not deteriorate with time. Damage due to settlement is relatively easy to repair in soil caps. These two alternatives are therefore given a score of 9.5.

Alternative 6 (FML Cap) is reasonably reliable, and is given a score of 9. The score is less than the soil cap alternatives because FML will deteriorate and lose effectiveness over time. It is much more likely to rupture (e.g., with settlement) or leak than soil-based caps, and much harder to repair. In contrast, soil liners tend to be self-sealing.

Alternative 7 (FML/GCL Cap) provides 2 liners, so that one liner may remain intact to offset failure of the other liner. However, this enhanced effectiveness was the basis for the score for effectiveness. The GCL layer is thin and just as susceptible to rupture with settlement as FML. An FML/GCL cap would be more difficult to repair than an FML or soil cap. An FML/GCL cap is not as reliable at maintaining the estimated high level of effectiveness. Alternative 7 is therefore given a lower score of 8.5.

9.4.1.3 Overall Score for the Long-Term Effectiveness and Reliability Criterion

The overall score for the criterion of long-term effectiveness and reliability is taken as the average of the two sub-criteria, which gives equal weight to the sub-criteria. The overall criterion scores are:

Alternative	Score
Alternative 1: No Action	0
Alternative 2: Institutional Controls	1
Alternative 4: Soil Cap	7.6
Alternative 5: Low-Permeability Soil Cap	8.9
Alternative 6: FML Cap	9
Alternative 7: FML/GCL Composite Cap	9
Alternative 9: Excavation and Disposal	7

9.4.2 Short-Term Effectiveness

Alternative 1 (No Action) does not subject site workers to any risk and would take no time to complete; therefore, this alternative is given a score of 10. Alternative 2 (Institutional Controls and Monitoring) involves relatively little site work and could be completed in about 2 months; therefore, this alternative is given a score of 9.

On the other extreme, there are major risks involved with trench excavation in Alternative 9 (Excavation and Disposal), as discussed in Section 8.2.6. In addition, Alternative 9 creates risk of human and ecological exposure through potential off-site release of chemicals during excavation and off-site transport of waste. Alternative 9 would take between one and two years to complete, depending on the degree of excavation difficulties encountered. Therefore, Alternative 9 (Excavation and Disposal) is given a score of 0.

The capping alternatives have greater short-term effectiveness than excavation and disposal, but less than Alternatives 1 and 2. For cap alternatives, the relative complexity of the caps is a measure of the relative man-hours required, and therefore the relative worker risk. All of the cap alternatives would take about one year to complete. On this basis, the cap alternatives are scored as follows:

Alternative	Score
Alternative 4: Soil Cap	7
Alternative 5: Low-Permeability Soil Cap	6.8
Alternative 6: FML Cap	6.6
Alternative 7: FML/GCL Cap	6.4

9.4.3 Reduction in Toxicity, Mobility and Volume

Treatment is the most effective means of providing permanent reduction in toxicity, mobility, and volume. The only alternative that would provided treatment is Alternative 9 (Excavation and Disposal). However, the need for treatment has not been identified, and treatment would be provided only to the extent required for landfill disposal. Intact or partially intact drums of liquid wastes, if found, would require incineration or other treatment. Alternative 9 is given a score of 5 to reflect the partial treatment that this alternative is presumed to provide.

Alternatives 1 (No Action) and 2 (Institutional Controls and Monitoring) do not provide any reduction in toxicity, mobility, and volume, and are therefore given scores of 0.
The cap alternatives (4 through 7) reduce infiltration through waste and affected soil, which decreases the potential for constituent migration into groundwater and therefore decreases the mobility of these constituents. These alternatives are therefore given scores of 2.

9.4.4 Implementability

Alternative 1 (No Action) would be the easiest to implement; therefore, it is given a score of 10. Alternative 2 (Institutional Controls and Monitoring) would be very easy to implement, and is therefore given a score of 9.

On the other extreme, as discussed in Section 8.2.6, there would be severe difficulties in attempting to excavate the trench. The feasibility of excavating waste from the trench is questionable, and excavation would not attempt to find and remove any waste that might be present below the water table. Therefore, Alternative 9 (Excavation and Disposal) is given a score of 0.

All of the cap alternatives would be much easier to implement than Alternative 9. Alternative 4 (Soil Cap) would be the easiest to implement, and is given a score of 7. Alternative 5 (Low-Permeability Soil Cap) is given the slightly lower score of 6.8 because it requires compaction to a permeability specification.

Synthetic liners require installation by specialized contractors. The liners are subject to puncture or rupture during installation, and require careful QA/QC. Alternative 6 (FML Cap) is therefore less implementable than Alternatives 4 and 5, and is given a score of 6.4. Alternative 7 (FML/GCL Cap) is given a lower score of 6, because it has two liners in its cap and is correspondingly more difficult to install.

9.4.5 Net Benefit (Overall Non-Cost Evaluation)

The net benefit of the alternatives is determined by combining the criteria scores with the scores weighted based on the relative values assigned to the criteria (see Section 9.3). The net benefit, or overall non-cost scores, are given in Table 9-2. Using these scores, the preference ranking of the alternatives before consideration of cost is as follows (most to least preferred):

1. Alternative 5 (Low-Permeability Soil Cap)
2. Alternative 6 (FML Cap)
3. Alternative 7 (FML/GCL Cap)
4. Alternative 4 (Soil Cap)
5. Alternative 2 (Institutional Controls and Monitoring)
6. Alternative 1 (No Action)
7. Alternative 9 (Excavation and Disposal).

Of these, based on evaluation of threshold criteria (Section 9.1), Alternatives 1, 2, and 4 do not meet minimum requirements.

It should not be surprising that Alternative 9 (Excavation and Disposal) has an overall score less than Alternative 1 (No Action). This ranking reflects the many problems associated with excavation and the uncertain benefit (i.e., lack of reliability). Alternative 9 (Excavation and Disposal) would be much more likely than Alternative 1 (No Action) to cause actual harm to humans in the form of construction accidents for site workers and traffic accidents in the community. It would also be much more likely to cause exposure to waste constituents, meaning greater risk to both human and ecological receptors. These known risks must be balanced against the potential risks of no action.

9.4.6 Cost

The estimated costs for the alternatives are summarized in Table 9-2. Detailed cost estimates are presented in Appendix H. The cost for Alternative 1 (No Action) is zero because it does not include any remedial action or monitoring. The estimated cost for Alternative 2 (Institutional Controls and Monitoring) is approximately $0.3 million. The estimated costs for the capping alternatives (4 through 7) range from $0.9 million to $1.3 million. The estimated cost for Alternative 9 (Excavation and Disposal) is $24 million.

The cost estimates in this FS are based on the description of the alternatives and associated design assumptions in Chapter 8. The design assumptions used here are representative and sufficient for the purposes of comparative evaluation of the alternatives, but are not necessarily the same as the design basis that would be used for the final, detailed design. Pre-design investigations would be included in the final design phase for any of these remedial actions, and the results of these investigations could result in changes from the preliminary designs presented in this FS.

The estimates were prepared to allow comparative evaluation of alternatives, not for budgeting purposes. The design basis is subject to change during final, detailed design of the selected alternative, and these changes would affect the cost of the remedy. The uncertainties in the FS designs and associated cost estimates are such that actual costs could vary significantly from these estimates. However, the uncertainty in the *relative* cost of the alternatives is much less than the uncertainty in the magnitude of the costs, and these cost estimates are suitable for comparative evaluation of the alternatives. Cost uncertainties were estimated stochastically (probabilistically), and are presented and discussed in the uncertainty analysis (Section 9.4.8).

9.4.7 Cost : Benefit Analysis and Overall Evaluation

Under WAC 173-340-360(5)(d)(vi), "a cleanup action shall not be considered practicable if the incremental cost of the cleanup action is substantial and disproportionate to the incremental degree of protection it would achieve over a lower preference cleanup action." The determination of practicability is made using an analysis of cost vs. benefit. The cost-benefit analysis can be performed quantitatively using the overall scoring of the non-cost criteria as the net benefit.

Figure 9-1 shows a graph of cost versus net benefit for all of the alternatives. To show the differences between cap alternatives better, Figure 9-2 graphs cost versus net benefit for just the cap alternatives. The error bars on these graphs show the range from the 10th to the 90th percentiles from the stochastic uncertainty analysis (see Section 9.4.8).

The ratio of net benefit to estimated cost, which is a measure of cost-effectiveness, is given in Table 9-2. On a strict cost:benefit basis, Alternative 2 (Institutional Controls and Monitoring) would be preferred if it met the threshold criteria. Alternative 5 (Low-Permeability Soil Cap) provides the next-best cost-effectiveness.

However, the MTCA regulations refer to incremental cost and benefit. To evaluate incremental cost-effectiveness, the difference in cost between alternatives is calculated, going from the least costly alternative to the most costly. The corresponding difference in net benefit (overall non-cost score) is then calculated. Dividing the incremental benefit by the incremental cost results in a value that is the incremental cost-effectiveness. These values are shown for the alternatives on Table 9-2.

Based on the cost-benefit graphs (Figures 9-1 and 9-2) and the incremental cost-effectiveness values (Table 9-2), two key conclusions can be drawn:

1. In the non-cost evaluation (Section 9.4.5), Alternative 9 (Excavation and Disposal) has already been shown to be a poor choice. In addition, Alternative 9 has very poor incremental cost-effectiveness. In other words, the incremental cost of the cleanup action is clearly substantial and disproportionate to the incremental degree of protection it would achieve (if any) over a lower preference cleanup action. Alternative 9 therefore does not meet the requirements of MTCA for a preferred alternative.

2. Alternative 5 (Low-Permeability Soil Cap) provides the best incremental cost-effectiveness, in addition to providing the best net benefit. Alternative 5 meets all threshold criteria (protection of human health and the environment, compliance with cleanup standards, compliance with ARARs, and provision for compliance monitoring). It provides the optimum combination of long-term effectiveness and reliability, short-term effectiveness, implementability, and reduction of toxicity, mobility, and volume. In addition, this alternative provides good cost:benefit. Considering the criteria and approach specified in WAC 173-340-360(5), Alternative 5 is the remediation alternative for the Landsburg Mine site that is "permanent to the maximum extent practicable", and is therefore the preferred alternative.

9.4.8 Uncertainty Analysis

The uncertainties in the evaluation of the alternatives have been analyzed stochastically (probabilistically). For the analysis, the evaluation scoring, net benefit calculations, and cost estimates were implemented in a computer spreadsheet (i.e., Table 9-2 and the Appendix G cost tables were set up in Excel®). Probability distribution functions (PDFs) were then estimated for non-cost scores, relative criteria values, and key cost parameters (documented in Appendix I). Using these PDFs, a Monte Carlo simulation (i.e., stochastic analysis) was performed using Crystal Ball®, an Excel add-in. This analysis results in estimated PDFs for selected calculated values, in this case the net benefit and costs of the alternatives. The output from this analysis is summarized in Table 9-3, and details are provided in Appendix I.

The error bars in Figures 9-1, 9-2, and 9-3 show the range from the 10th to the 90th percentiles for the values from the stochastic analysis. In other words, it is estimated that there is an 80% probability that the value of the calculated parameter (net benefit or cost) lies in the range shown by the error bars. The difference between Figures 9-2 and 9-3 is the value shown as the "best estimate." Figure 9-2 uses the deterministic values of net benefit and cost as the best estimates (Table 9-2). Figure 9-3 uses the mean values of the probabilistic analysis as the best estimates (Table 9-3). Of significance, as shown by these figures, the relative cost-effectiveness is not changed by which set of values is used for the best estimate.

As shown in Figure 9-1, there is no overlap in ranges (error bars) between the cap alternatives (4 through 7) and Alternative 9 (Excavation and Disposal). This indicates that no defensible combination of alternative scores and relative criteria values would result in preference for Alternative 9.

In addition, Alternative 9 has a very large uncertainty in cost ($9 million to $48 million), indicating that selection of this alternative would involve a very large cost risk. This uncertainty is primarily due to uncertainty in 1) the quantity of volume of waste and affected soil that would require disposal, and 2) the average unit cost of this disposal. Unit disposal costs could range from less than $50/yd^3 for non-hazardous waste landfill to over $1,000/yd^3 for incineration, with the average unit cost being somewhere in between. The deterministic estimate is based on the estimated volume given in Table 9-1 and an average unit cost for disposal (including any required treatment) of $300/yd^3.

Although the error bars for Alternative 2 (Institutional Controls and Monitoring) and Alternative 1 (No Action) overlap, this is somewhat misleading. The net benefits of these two alternatives will rise and fall together, given that Alternative 1 is the baseline for comparison. Consequently, Alternative 2 would virtually always be preferred relative to Alternative 1.

The uncertainty in relative ranking of the cap alternatives (4 through 7) is somewhat more complex. As can be seen from Figure 9-2, there is significant overlap in the ranges for net benefit and cost for these alternatives. However, the net benefits in the cap alternatives are somewhat correlated (i.e., the scores rise and fall together), in that they are based on a common general technology (capping) and have the common benefits and drawbacks of backfilling the trench.

Given the definition of the cap designs, Alternative 5 (Low-Permeability Soil Cap) will always provide at least some improvement in long-term effectiveness and reliability over Alternative 4 (Soil Cap), and in most cases give better net benefit. Alternative 5 will also always be more expensive than Alternative 4, although the differential cost (and thus the incremental cost-effectiveness) could vary significantly if off-site soil is required for the low-permeability cap (raising its cost).

Similarly, because both cap designs include an FML liner, Alternative 7 (FML/GCL Cap) will always provide equal or better long-term effectiveness and less reliability than Alternative 6 (FML Cap). Alternative 7 will also always cost more than Alternative 6. Based on the non-cost scores and associated PDFs, the probability that Alternative 7 would have better net benefit than Alternative 6 is low.

The primary uncertainty with a significant possibility of affecting selection between cap alternatives is the assumed availability of sufficient suitable site soil for construction of the low-permeability soil cap. Based on available data (see Section 8.2.4 and Appendix J), it appears that this assumption is warranted and has a reasonable probability of being valid. However, if this assumption is not true, then the differential cost between Alternative 5 (Low-Permeability Soil Cap) will change. In the extreme, Alternative 5 could be more expensive than Alternative 6 (FML Cap). Given that the net benefit of these two alternatives is very close, selection of Alternative 5 over Alternative 6 is primarily based on their relative cost-effectiveness. Any factor significantly affecting the cost of either alternative could change the relative ranking of these two alternatives. Therefore, although it is considered most probable that Alternative 5 is the best alternative, Alternative 6 should be retained as a contingency.